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(71) Applicant: AT&T Corp.
New York, NY 10013-2412 (US)

(72) Inventor: Ziger, David H.
Altamonte Springs, New Jersey 32714 (US)

(74) Representative:
Watts, Christopher Malcolm Kelway, Dr. et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green Essex, IG8 0TU (GB)

(54) Method and arrangement for characterizing micro-size patterns

(57) A method and arrangement for characterizing features of a patterned material (2) on an underlying layer (7) is disclosed. According to the method, the patterned material is subjected to radiation (9) including a range of wavelengths such that the patterned material absorbs more radiation than the underlying layer, and the underlying layer reflects more radiation than the patterned material. Zeroth order reflected radiation (11) is measured and the reflectance measurement is expressed as a spectrum of the intensity of the reflected radiation as a function of the wavelength of the reflected radiation, or as an average reflectance over a range of wavelengths. The reflectance measurement can be correlated with features of the patterned material. An arrangement of equipment is disclosed for characterizing features of a patterned material according to the method.

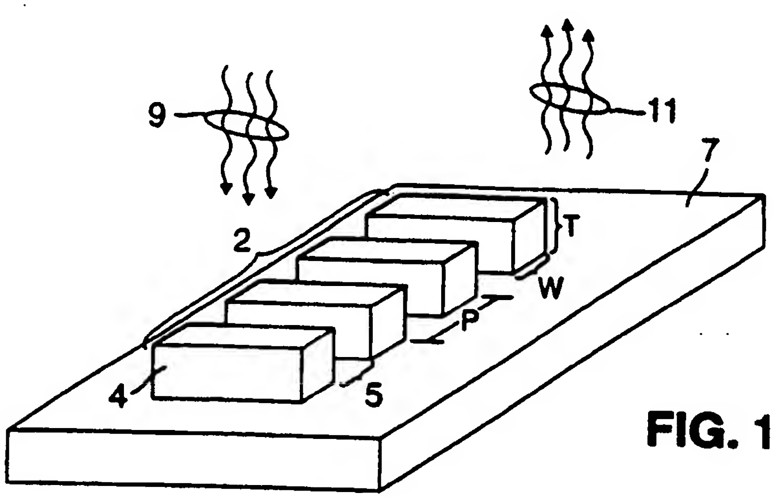

FIG. 1

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wavelengths as defined above. Furthermore, as the uncovered area of the substrate, such as the substrate 7 of FIG. 1, increases, so does the intensity of the reflected radiation 11.

Thus, a pattern, such as a line and space pattern, may be characterized according to a first embodiment of the present invention, which is illustrated by steps 90 through 120 of the flow diagram shown in FIG. 2. In step 90, an arrangement comprising a patterned layer on a substrate, such as a line and space pattern on a wafer, is obtained. Typically, such an arrangement would be diverted from a lithographic processing line wherein mechanical features are photolithographically reproduced in, for example, a semiconductor arrangement. In step 100, the arrangement is illuminated by radiation. The radiation includes a range of wavelengths such that the film absorbs more radiation than the substrate, and the substrate reflects more radiation than the film. As will be appreciated by those skilled in the art, such information may be obtained by measuring the spectra of the film material and the substrate over a range of wavelengths or consulting optics reference texts. A relatively small amount of contrast, i.e., the reflectivity of the film versus the reflectivity of the substrate, is required. Obviously, the more sensitive and stable the optics for collecting the reflected radiation, the less contrast is required. Furthermore, the wavelength range described above should be suitable for resolving the micro-size features of interest of the patterned film. For example, if the line width of a line and space pattern is to be characterized, and the line width is about 0.5 micrometers (μm) (500 nm), suitable wavelength radiation for resolving the line width is less than about 300 nm. Based on empirical evidence, suitable wavelength radiation should have a maximum wavelength of about 65 percent of the size of the feature of interest.

In the next step 110, the amount of zeroth order reflected radiation from the patterned film and the substrate is measured. In step 120, a reflectance spectra is defined by expressing the reflectance as a function of the wavelength of the reflected radiation. Such a reflectance spectra uniquely characterizes the pattern. The Nanometrics 4000 Series, manufactured by Nanospec Corp. of Sunnyvale, Ca., the Prometrix 1050 UV, manufactured by Prometrix of Sunnyvale, Ca., or other equipment known to those skilled in the art that is suitable for subjecting a pattem to appropriate wavelength radiation and receiving and measuring the reflected radiation may be used to obtain the reflectance spectrum. Such equipment will be referred to herein as a spectral reflectometer. Preferably, the spectral reflectometer should include a suitably programmed processor for collecting and processing the reflectance data, i.e., defining a reflectance spectrum or the like. Alternatively, a separate processor, such as a suitably programmed computer, may be used for data processing. The spectral reflectometer should be capable of measuring zeroth order reflected radiation. In use, the spectral reflectometer is adjusted so that its light source, typically a broad band source, is focussed over the pattern to be characterized. The beam from the light source typically illuminates an area about 70 μm x 70 μm. The user also selects the range of wavelengths over which the reflectance data is to be measured. An exemplary spectral reflectometer is described in more detail below in conjunction with a description of an arrangement according to the present invention.

A second embodiment of the present invention is described by steps 90 through 150 of FIG. 2. Once the first arrangement is characterized according to steps 90 through 120, a second arrangement is obtained for characterization according to step 130. As indicated in step 140, steps 100 through 120 are then repeated for the second arrangement. This may be repeated for a third and further arrangements. Finally, in step 150, the reflectance measurements of the arrangements may be organized as a database or otherwise archived. Such a data base may be stored in the memory of a suitably programmed computer by methods known to those skilled in the art.

A specific application of the first and second embodiments of the present invention are discussed below in conjunction with FIGS. 3A, 3B and 4. These Figures illustrate the suitability of using a reflectance spectrum to uniquely characterize a patterned layer.

FIG. 3A shows three arrangements 15a, 20a and 30a of photoresist on a silicon substrate. FIG. 3B shows three reflectance spectra 15, 20 and 30 which were obtained using the Nanometrics 4000 Series spectral reflectometer by illuminating the arrangements 15a, 20a and 30a, respectively, with radiation. In particular, the reflectance spectra 15, 20 and 30 were obtained by subjecting the arrangements 15a, 20a and 30a to ultraviolet light (UV) consisting of a plurality of wavelengths from about 200 to 800 nm.

The arrangements 15a and 20a were micro-size line and space pattems formed from novalac containing photoresist on a silicon substrate 7a, 7b. The arrangements 15a and 20a both had a pitch P_1, P_2, respectively, of 1.0 μm and a line width W_1, W_2, of about 0.5 and 0.4 μm, respectively. The lines 5a of photoresist comprising the arrangement 15a had a thickness T_1 of 1.175 μm, and the lines 5b of the arrangement 20a had a thickness T_2 of 1.70 μm. For such an arrangement, radiation between about 200 to 300 nm, referred to as deep UV (DUV), is absorbed more strongly by the lines of photoresist 5a, 5b than the substrate 7a, 7b, reflected more strongly by the substrate than the lines of photoresist, and is suitable for measuring line widths of 0.4-0.5 μm. Such a range of wavelength is therefore within the teachings of the present invention.

The arrangement 30a comprises a layer 6 of unpatterned novalac containing photoresist on a silicon substrate 7c. The layer 6 of unpatterned photoresist had a thickness T_3 of 1.175 μm, The spectra 30 for the unpatterned layer 6 of photoresist of arrangement 30a is rel-

atively flat in the DUV. The spectra 30 does not show the regular interference patterns, at DUV wavelengths, which the spectras 15 and 20 for the patterned photoresist exhibit.

There are more interference fringes 22b in the reflectance spectrum 20 than interference fringes 22a in the reflectance spectrum 15. The increase in interference fringes in the reflectance spectrum 20 may be due to the comparatively thicker lines 5b of photoresist of the arrangement 20a in comparison to the lines 5a of the arrangement 15a. At wavelengths above about 300 nm, the photoresist becomes substantially more transparent to UV. Consequently, the reflectance spectra 15 and 20 are a convolution of reflectances from the air/photoresist interface, the air/substrate interface and the photoresist/substrate interface. This portion of the spectrum may contain some useful information, but, for the particular arrangements discussed in FIG. 3A, is not within the teachings of the present invention. Note that in the region from 200 to 300 nm, the reflectance spectra will be free from reflectances from the photoresist/substrate interface since the photoresist absorbs more light in this region of the spectrum.

Thus, the spectrum 15 from about 200 to 300 nm uniquoly characterizes a novalac on silicon line and space pattern having a pitch P_1 of 1.0 μm and lines 5a that have a width W_1 of 0.5 μm and a thickness T_1 of 1.175 μm. Likewise, the spectrum 20 from about 200 to 300 nm uniquely characterizes a novalac on silicon line and space pattern having a pitch P_2 of 1.0 μm and lines 5b that have a width W_2 of 0.4 μm and a thickness T_2 of 1.70 μm. As will be discussed later in this specification, information contained in this portion of the spectrum may be correlated to features of the pattern. Subjecting an unpatterned layer, however, such as the layer 6 of unpatterned novalac photoresist of arrangement 30a, to radiation below 300 nm, provides little if any useful information. This is because radiation of this wavelength is substantially absorbed by the novalac photoresist and there are no spaces or gaps in the unpatterned layer 6 so that radiation reflected from the substrate 7c creates the interference patterns observed for spectra 15 and 20. For this reason, the prior art method of measuring the thickness of a photoresist layer is accomplished using the longer wavelength portion of the spectrum, i.e., above 300 nm for novalac photoresist.

Note that the profile angle θ (see Fig. 3a, arrangement 15a) of the lines of a line and space pattern, i.e., the angle described by the stripes or lines of photoresist relative to the substrate, was constant for the above arrangements. Substantial variations in the profile angle θ may affect the reflectance spectrum.

A reflectance measurement of a pattern, such as a line and space pattern, having a particular size and configuration is substantially reproducible. FIG. 4 shows the reflectance spectra of wafers that were processed under identical conditions to produce a line and space pattern, similar to arrangements 15a and 20a, of novalac photoresist on silicon. The nominal line width of the pattern was 0.5 μm. The pattern had a pitch of the 1.0 μm. The thickness of the lines was 1.175 μm. The reflectance spectra of FIG. 4 are collectively given the reference numeral 50. As can be seen from FIG. 4, the six reflectance spectra comprising the spectra 50 are substantially identical.

As shown in FIG. 4, the reflectance spectrum of a patterned layer is reproducible outside of the range of wavelengths taught by the present invention. However, the portion of the spectrum not included within the present teachings is less readily correlatable to pattern feature size than the portion of the spectra within the present teachings, if correlatable at all. This is of particular significance for some of the following embodiments wherein the method of the present invention may be used to obtain quantitative information about a feature of a patterned layer, such as the micro-size line width of a line and space pattern. Such further embodiments of a method according to the present invention are illustrated by flow chart and block flow diagram in FIGS. 5A-5D and described below.

In step 200, an arrangement comprising a patterned layer on a substrate is subjected to radiation. In the next step 210, the radiation reflected from the arrangement is measured. The numerical value of the feature is determined in step 220 by using information obtained from previously obtained reflectance measurements. Step 220 may be accomplished using a number of methods, two examples of which are described below.

In a first embodiment, illustrated in FIG. 5B, archived data, obtained in steps 300 and 305, is compared, in step 310, with the reflectance spectrum of an uncharacterized pattern. The archived data or data base is obtained according to steps 300 and 305 wherein a number of reference patterns are formed and reflectance spectra are then obtained for such reference patterns. Features of interest for each reference pattern are measured by SEM or other suitable method. The reference reflectance spectra and measured values for features of interest for each reference pattern are organized into a data base or archive by methods known to those skilled in the art. By matching an uncharacterized pattern to an archived reference reflectance spectra, a value, i.e., the size of a feature of interest, may be determined.

In a second embodiment, illustrated in FIG. 5C, the numerical value of a feature may be determined by developing a correlation between the feature and reflectance. According to the second embodiment, reflectance measurements are obtained for a plurality of reference patterns of known structure. The numerical value of a feature of interest is regressed against the reflectance of the reference patterns over the range of suitable wavelengths, as previously described. The numerical value of the feature may then be expressed as a function of the reflectance. The correlation may be expressed algebraically or graphically. When developing a correla-

tion as described above, it is preferable to use the average reflectance over a range of wavelengths. Alternatively, the reflectance at the periodic maxima within a given reflectance spectra can be used. A linear regression may be used.

The steps discussed in FIGS. 5A-5C may be accomplished by the exemplary arrangement of equipment shown in FIG. 5D. The archived data or data base of reference reflectance measurements and measured values of various features of interest, such as the line width of a line and space pattern, may be obtained as follows. Reflectance measurements for a plurality of patterns are first obtained by equipment such as a spectral reflectometer 340 suitable for such purpose. Suitable reflectometers include the Nanometrics 4000 Series or the Prometrix 1050 UV.

A simplified block diagram of a spectral reflectometer 340 is shown in FIG. 5E. Radiation is provided by an illumination source 342. The illumination source 342 is typically a broadband source such as xenon arc lamp. Such a source typically provides radiation ranging in wavelength from about 220 to 800 nm. Illumination source 342 may also include various filters, shutters, a focus aperature and various drive solenoids and stepper motors, not shown in the Figure. Radiation from the illumination source 342 is focussed on a beam splitter 344. One beam, not shown, generated by the beam splitter 344 functions as a reference. This reference beam is guided to the spectrometer assembly 347 for processing. The other beam, identified by the reference numeral 343, is directed toward a wafer 345 and focused over the pattern to be characterized. Reflected radiation 346 is received by the spectrometer assembly 347. In the spectrometer assembly, reflected radiation 346 is typically resolved into its spectral components by a grating. Each spectral component of the reflected radiation 346, i.e., radiation of a particular wavelength, is reflected off the grating to a location dictated by that particular wavelength. Photodetectors positioned at such locations receive the radiation and generate an electrical signal proportional to the amount of incident radiation. Thus, a signal generated by a particular photodetector is associated with radiation having a particular wavelength. The various signals generated by the activated photodetectors are processed by the processor 348. A reflectance spectrum, average reflectance over a wavelength range or other expression of the amount of reflected radiation for a corresponding wavelength may then be calculated. The aforementioned discussion of the spectral reflectometer 340 is intended to provide an overview of its operation and some of its important elements. As known to those skilled in the art, the spectral reflectometer 340 typically includes other elements, not shown, for accomplishing various other functions.

Returning to the arrangement of FIG. 5D, a measurement device 350 is used to directly measure features of the plurality of patterns. A scanning electron microscope, such as the S7000 by Hitachi, Ltd. is suitable for performing such measurements. A suitably programmed microprocessor 360 receives, either directly or indirectly, the reflectance measurements and direct measurement data from the spectral reflectometer 340 and the measurement device 350 and stores such information in memory 370. Thus, for each pattern, a reflectance measurement, as well as values representative of measurements of features of the pattern, are stored in memory 370. Such information forms the archive or data base.

The microprocessor 360 is preferably programmed to regress the reflectance measurement and direct measurment data stored in memory 370 to develop a correlation as discussed above in conjunction with FIG. 5C.

Once a data base has been created in memory 370, the arrangement depicted in FIG. 5D may be used determine the numerical value of a feature of an unmeasured pattern as follows. A reflectance spectrum may be obtained for an unmeasured pattern using the spectral reflectometer 340. Such spectral information is received by the microprocessor 360 which is suitably programmed to compare the reflectance spectrum to the reference reflectance spectra stored in the memory 370. If a match is found between reflectance spectra stored in memory and the reflectance spectra corresponding to the unmeasured pattern, then the reference pattern and the unmeasured pattern are substantially identical. Measurement data from memory 370 corresponding to the matching reference pattern is displayed. Thus, the size of a feature of an unmeasured pattern may be determined. If an average reflectance value, rather than a full reflectance spectra, is obtained from the spectral reflectometer 340, then such a value may be used to estimate the size of a feature by applying a previously developed correlation, as discussed above, to the average reflectance value.

This exemplary method is particularly well-suited for applications having one degree of freedom. For example, for a line and space pattern, the thickness T and profile angle θ of the lines, such as lines 5a and 5b of FIG. 3A, and the pitch of the pattern should be invariable, the variable being the line width W. If the only variable is the line width W, then differences in the reflectance spectra obtained for different line and space patterns result from differences in the line width W of such patterns. Thus, the line width W of the pattern being measured is equal to the line width of the pattern from which the matching reference reflectance spectra was obtained. Alternatively, line width may be held constant and some other parameter may be varied.

Specific examples of using the present invention to obtain quantitative information regarding a pattern are discussed below in conjunction with FIGS. 6 and 7.

FIG. 6 shows four reflectance spectra 40, 42, 44 and 46 that were obtained for four arrangements, 40a, 42a, 44a and 46a, respectively, using the Nanometrics 400 Series spectral reflectometer. The arrangements,

not shown, comprised patterned novalac photoresist on silicon. The patterned photoresist of arrangements 40a, 42a, 44a and 46a was patterned into line and space patterns, similar to those shown in FIGS. 1 & 3A. The line and space pattern of each of the arrangements 40a - 46a had a 1.0 µm pitch. The thickness and profile angle of the lines and of the four patterns was substantially the same. The line width of the lines of the four patterns was different, however, decreasing from a maximum line width in arrangement 40a to a minimum width in arrangement 46a.

It can be seen from the four spectra 40 - 46 that the average reflectance, over a range of wavelengths, increases as the line width decreases. According to the present invention, linewidth can be expressed as a function of average reflectance. FIG. 7 illustrates such a correlation 60 between line width and reflectance between 220 to 300 nm for such a 1.0 µm pitch line and space pattern. The correlation 60 shown in FIG. 7 may be represented algebraically by the following equation, $LW = 0.703 - 1.746 * Ref_{(220\text{-}300nm)}$, where LW is the line width in µm of a line and space pattern, and $Ref_{(220\text{-}300nm)}$ is the average reflectance as measured over the range of 220 to 300 nm.

In a further embodiment, illustrated in FIGS. 8A and 8B, a method in accordance with the present invention may be used for quality control of a lithographic writing process. A lithographic writing process may be used to produce a pattern having desired features and feature size. A number of parameters affect the ability to produce a pattern having desired features using such a process. For example, the age of photoresist being patterned, the chemical composition of the photoresist developer solution, and, perhaps most importantly, the dose of radiation used to expose the photoresist will all affect the resulting pattern. As such, it is desirable to routinely monitor the pattern being produced.

According to step 400 of FIG. 8A, test patterns are developed, reflectance measurements are obtained and features of the test patterns are measured by suitable means such as SEM. In step 410, the feature of interest, such as the line width of a line and space pattern, may be correlated to reflectance according to the present invention. Alternatively, a reference reflectance spectrum is obtained for a pattern having the specific features to be reproduced in the manufacturing process. According to step 420, the operating parameters of the writing process are then set to produce a pattern having a specific reflectance, i.e., one which will result in a pattern having a desired feature, such as a 0.5 µm line width. In step 430, regular production patterns are periodically sampled, preferably according to statistical methods, and a reflectance measurement is obtained for each sampled pattern. The reflectance measurement for each sampled pattern is then compared, as appropriate, to the reference spectrum or correlation. If the reflectance measurement from a sampled pattern deviates from the reference or correlation, then the pattern being produced is off-specification. Once alerted to off-specification production, the operator of the lithographic writing process may check the various parameters to determine what parameter should be adjusted, as indicated in step 440.

The aforementioned steps may be accomplished by the exemplary arrangement of equipment depicted in FIG. 8B. A wafer, coated with photoresist, such as SPR-513 resist, is placed within a photolithographic exposure tool 450. In the photolithographic exposure tool 450, the photoresist is exposed to radiation, typically UV, through a patterned mask. A suitable exemplary photolithographic exposure tool 450 is a stepper, well known to those skilled in the art. Several exemplary steppers are described in U.S. Pat. Nos. 4,616,908, 4,206,494 and 4,425,037. Next, the photoresist layer is developed in developer 460. Tetramethyl-ammonium-hydroxide is typically used as a developer fluid. Development yields the patterned layer, which may have the form of a line and space pattern, for example. For continued processing, the patterned wafer is next etched in an etcher 500 and then the photoresist remaining on the wafer is removed. In this manner, a pattern, such as a line and space pattern, may be etched into the wafer to form a mechanical feature such as a optical diffraction grating.

On a periodic basis, wafers may be diverted, after development, from the etcher to a spectral reflectometer 470 wherein a reflectance measurement is obtained. Such spectral information is then received by a microprocessor 480 which is programmed to compare such information to a reference pattern or apply it to a correlation stored in a memory 490. Such a reference pattern or correlation is stored in memory as previously discussed. If a deviation exists between the reflectance measurement from the diverted sample and that of the reference, then an operator is alerted by a visual or audible alarm that off-specification patterns are being produced and that the operation should be checked and adjusted as appropriate.

It should be understood that while the embodiments described herein are illustrative of the principles of this invention and that various modifications may occur to, and be implemented by, those skilled in the art without departing from the scope and spirit of the invention. For example, the method of the present invention may be used to quantify features other than the line width of a line and space pattern. Further, while the embodiments discussed herein are directed to applications wherein the substrate is generally more reflective than the patterned layer, the contemplated scope of the present invention includes arrangements wherein the patterned layer is generally more reflective than the substrate and wherein the arrangement is irradiated by radiation having a suitable range of wavelengths such that the patterned material reflects more radiation than the substrate, and the substrate absorbs more radiation than the patterned material.

Claims

1. A method for characterizing an arrangement having a patterned layer of photoresist disposed on an underlying layer, the patterned layer of photoresist having a micro-size first feature, comprising the steps of:

(a) subjecting the arrangement to radiation having a range of wavelengths such that the patterned layer of photoresist absorbs more radiation than the underlying layer, and the underlying layer reflects more radiation than the patterned layer of photoresist, and further characterized by a range of wavelengths suitable for measuring the first feature of the patterned layer of photoresist;
(b) measuring the zeroth order reflected radiation from the arrangement;
(c) expressing the amount of zeroth order reflected radiation as a reflectance measurement; and
(d) comparing the reflectance measurement for the arrangement to reflectance measurements obtained for a plurality of reference arrangements each having a patterned layer of photoresist disposed on an underlying layer, and wherein each patterned layer of photoresist has the first feature.

nanometers.

2. The method of claim 1, wherein a plurality of values, each of which is indicative of the first feature of the patterned layer of one of the reference arrangements, is obtained.

3. The method of claim 2, wherein the reflectance measurement is an average reflectance and wherein the reflectance measurements and the plurality of values corresponding to the reference arrangements are used to develop a correlation determinative of the first feature as a function of the average reflectance and step (d) further comprises applying the correlation to the reflectance measurement of the arrangement to determine the first feature of the arrangement.

4. The method of claim 1 or 3, wherein the patterned layer of photoresist is a line and space pattern defined by a plurality of stripes of photoresist.

5. The method of claim 3 or 4, wherein the plurality of stripes are characterized by a width, and the first feature of the patterned layer is the width of the stripes of photoresist.

6. A method for characterizing a first arrangement having a line and space pattern of material disposed on a substrate, wherein the line and space pattern is characterized by a micro-size line width, comprising the steps of:

(a) subjecting the first arrangement to radiation having a range of wavelengths such that the material absorbs more radiation than the substrate, and the substrate reflects more radiation than the material, and further characterized by a range of wavelengths suitable for measuring the line width;
(b) measuring the zeroth order reflected radiation from the first arrangement;
(c) expressing the amount of zeroth order reflected radiation as a reflectance measurement; and
(d) measuring the line width of the line and space pattern.

7. The method of claim 6, wherein scanning electron microscopy is used for measuring the line width of the line and space pattern.

8. The method of claim 7, wherein there is a second arrangement having a line and space pattern of material disposed on a substrate, wherein the line and space pattern is characterized by a line width, further comprising the steps of:

(e) repeating steps (a) through (d) for the second arrangement.

9. The method of claim 8, wherein the measurements of the line width of the line and space patterns of the first and the second arrangements, and reference reflectance measurements comprising the reflectance measurements for the first and the second arrangements, are organized into a data base.

10. The method of claim 9, wherein there is a third arrangement having a line and space pattern of material disposed on a substrate, wherein the line and space pattern is characterized by a line width, further comprising the steps of:

(f) obtaining a reflectance measurment for the third arrangement by repeating steps (a) through (c); and
(g) comparing the reflectance measurement for the third arrangement to the reference reflectance measurements in the data base to determine the line width of the third arrangement.

11. The method of claim 1 or 10, wherein the material is photoresist comprising novalac resin, the underlying layer or substrate is silicon, and wherein the radiation that the first arrangement is subjected to

comprises wavelengths from about 200 to 300 nanometers.

12. A method for determining a numerical value for a micro-size feature of a patterned layer disposed on an underlying layer, comprising the steps of:

(a) irradiating the patterned layer with radiation having a range of wavelengths such that the pattern absorbs more radiation than the underlying layer, and the underlying layer reflects more radiation than the pattern, and wherein the range of wavelengths is suitable for measuring the feature of the pattern;
(b) measuring a reflectance signal, which signal corresponds to the zeroth order reflected radiation from the patterned layer and the underlying layer; and
(c) determining the numerical value for the feature of the patterned layer using information obtained from reference reflectance measurements, obtained according to steps (a) and (b), for patterned layers for which a numerical value of the feature is known.

13. The method of claim 12, wherein the step of determining the numerical value for the feature further comprises comparing the reflectance signal to a data base of reference reflectance spectras comprising reflectance signals obtained according to steps (a) and (b), for patterned layers for which a numerical value of the feature is known, and matching the reflectance signal to one of the reference reflectance spectra which has substantially the same reflectance signal.

14. The method of claim 12, wherein an average reflectance over the range of wavelengths is obtained from the reflectance signal measured in step (b) and wherein the step of determining the numerical value for the feature further comprises applying a previously developed correlation that provides a numerical value for the feature as a function of average reflectance to the reflectance signal measured in step (b).

15. The method of claim 13, wherein the pattern is a line and space pattern defined by a plurality of spaced lines formed of novalac containing photoresist, and wherein the pattern is characterized by a pitch and the lines are characterized by a width and wherein the feature of the pattern is the width of the lines, and wherein the underlying layer is silicon, and the radiation irradiating the line and space pattern comprises wavelengths about 300 nanometers or less.

16. The method of claim 14, wherein the pattern is a line and space pattern defined by a plurality of spaced lines formed of novalac containing photoresist, and wherein the pattern is characterized by a pitch and the lines are characterized by a width and wherein the feature of the pattern is the width of the lines, and wherein the underlying layer is silicon, and the radiation irradiating the line and space pattern comprises wavelengths about 300 nanometers or less.

17. A method for controlling a lithographic writing process operable to generate a first pattern in a first layer which is disposed upon a second layer of an arrangement, which first pattern is characterized by a first micro-size feature having a desired size, wherein a plurality of operating parameters of the lithographic writing process may be adjusted to vary the size of the first feature, comprising the steps of:

(a) generating a pattern using the lithographic writing process;
(b) obtaining a reflectance measurement of the pattern generated in step (a);
(c) comparing the reflectance measurement obtained in step (b) to one of:

(i) a reference reflectance spectra obtained for the first pattern having the first feature of the desired size, and
(ii) a correlation that expresses the size of the first feature as a function of average reflectance;

(d) adjusting at least one of the plurality of operating parameters if the comparison of step (c) indicates a difference between the reflectance measurement of the pattern generated in step (a) and one of the reference reflectance spectra and the correlation; and
(e) repeating steps (a) through (d).

18. The method of claim 17 wherein the correlation of step (c) is obtained by:

developing test patterns having the first feature, which test patterns vary in terms of the size of the first feature;
obtaining an average reflectance of each of the test patterns;
measuring the first feature of each of the test patterns; and
developing a correlation determinative of the size of the first feature as a function of average reflectance.

19. A method for characterizing an arrangement having a patterned layer disposed on an underlying layer, the patterned layer having a micro-size first feature,

comprising the steps of:

(a) subjecting the arrangement to radiation having a range of wavelengths such that the patterned layer reflects more radiation than the underlying layer, and the underlying layer absorbs more radiation than the patterned layer, and further characterized by a range of wavelengths suitable for measuring the first feature of the patterned layer;
(b) measuring the zeroth order reflected radiation from the arrangement;
(c) expressing the amount of zeroth order reflected radiation as a reflectance measurement; and
(d) comparing the reflectance measurement for the arrangement to reflectance measurements obtained for a plurality of reference arrangements each having a patterned layer disposed on an underlying layer, and wherein each patterned layer has the first feature.

20. An apparatus for characterizing an arrangement having a patterned layer of photoresist disposed on an underlying layer, the patterned layer of photoresist having a micro-size first feature, comprising:

(a) a first device for obtaining a reflectance measurement;
(b) a memory for storing reference reflectance measurements obtained for a plurality of reference arrangements each having a patterned layer of photoresist disposed on an underlying layer, each patterned layer having the first feature; and
(c) a microprocessor, in communication with the memory, programmed to receive the reflectance measurement of the arrangement from the first device and compare said reflectance measurement to the reference reflectance measurements stored in the memory.

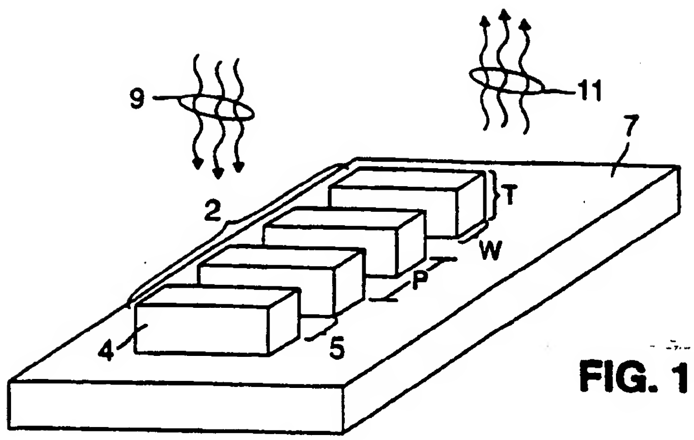

FIG. 1

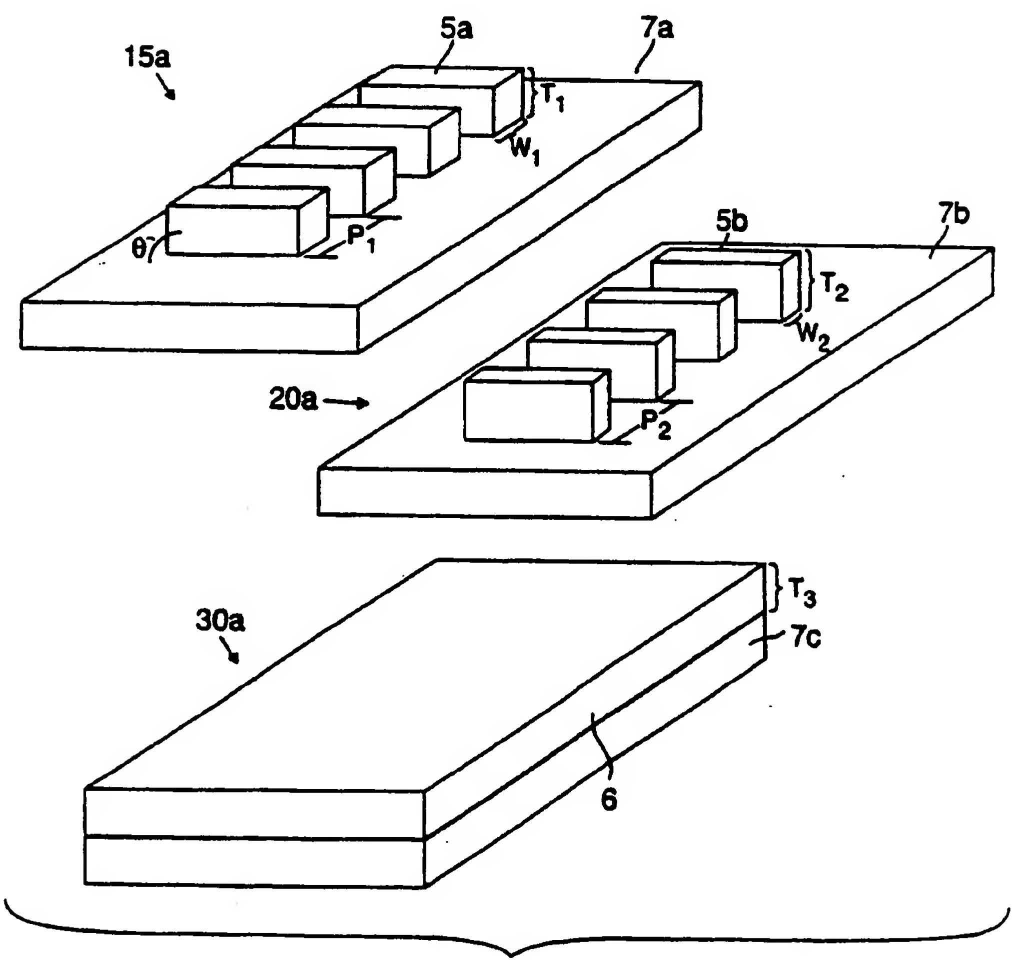

FIG. 3A

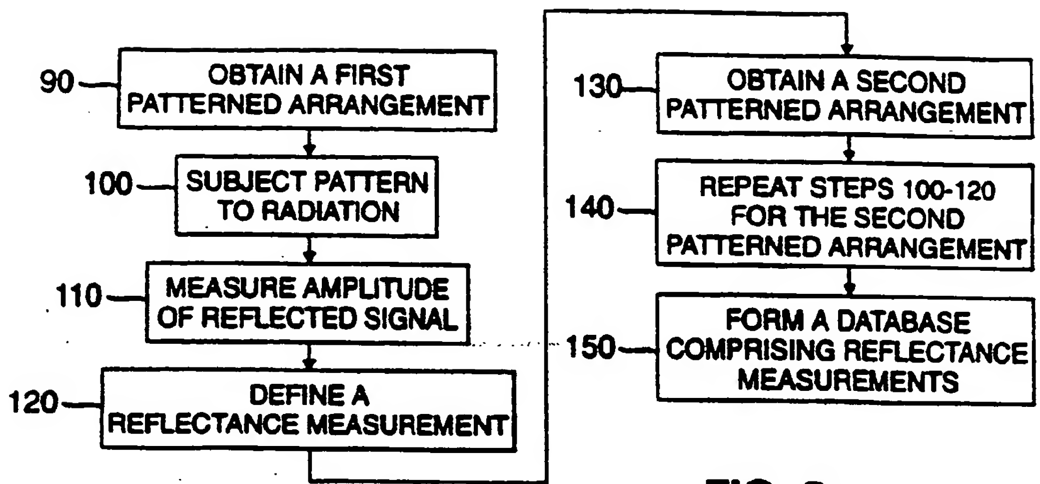

FIG. 2

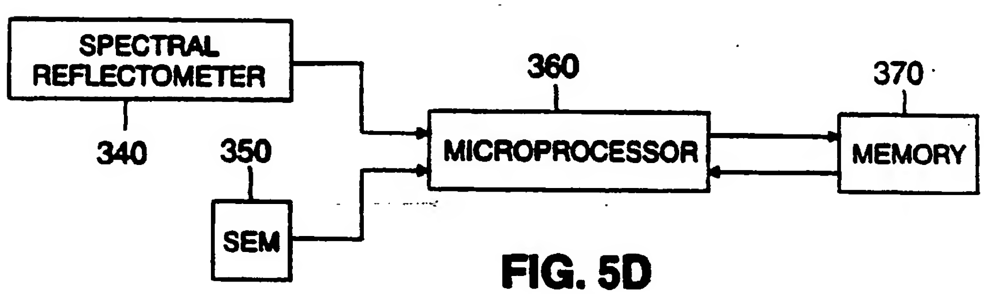

FIG. 5D

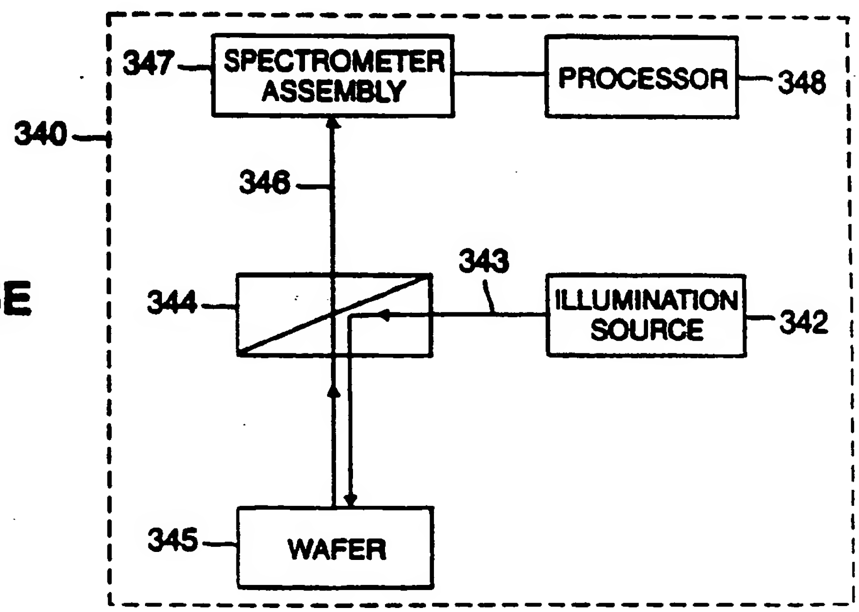

FIG. 5E

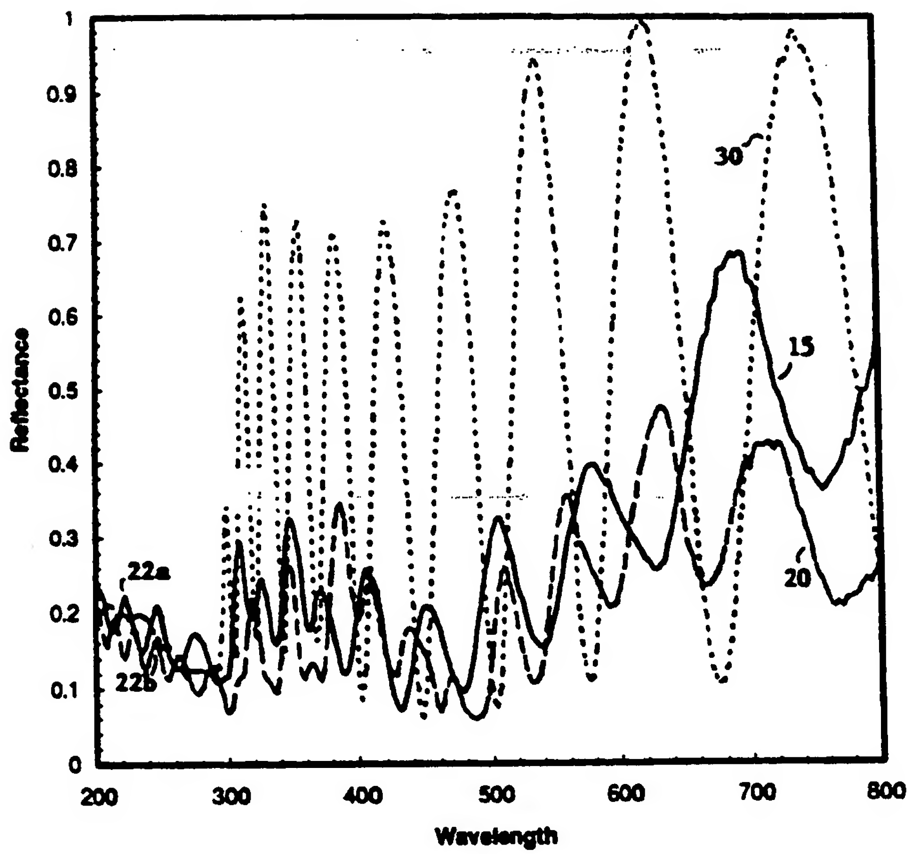
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Reflectance
200
300
400
500
600
700
800
Wavelength
22a
22b
30
15
20

FIG. 3B

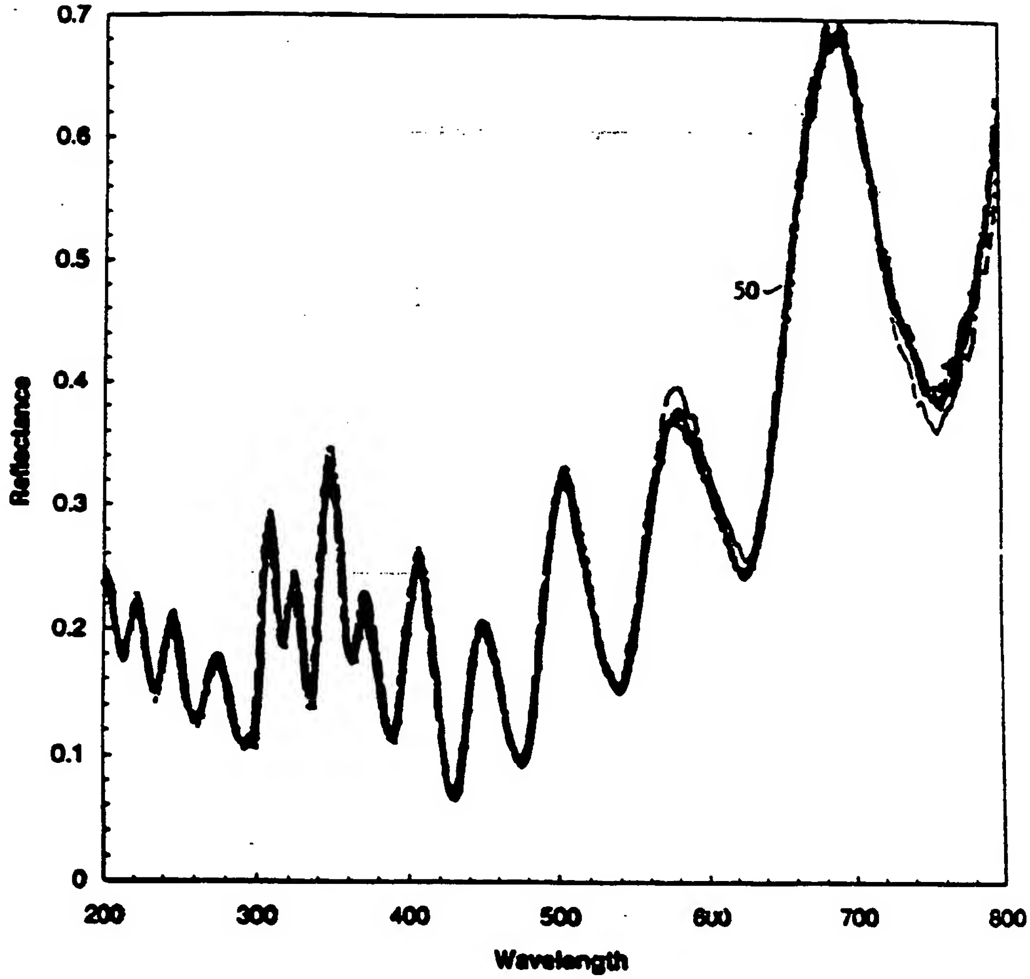
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Reflectance
50
200
300
400
500
600
700
800
Wavelength

FIG. 4

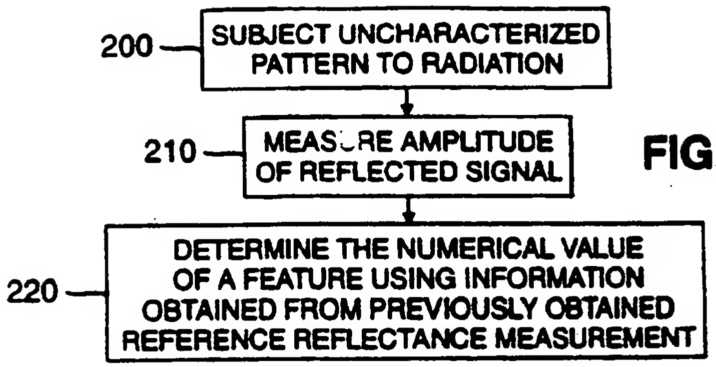

FIG. 5A

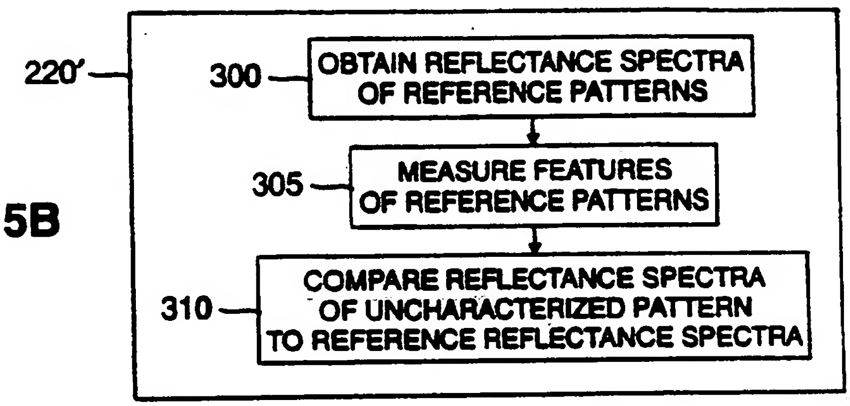

FIG. 5B

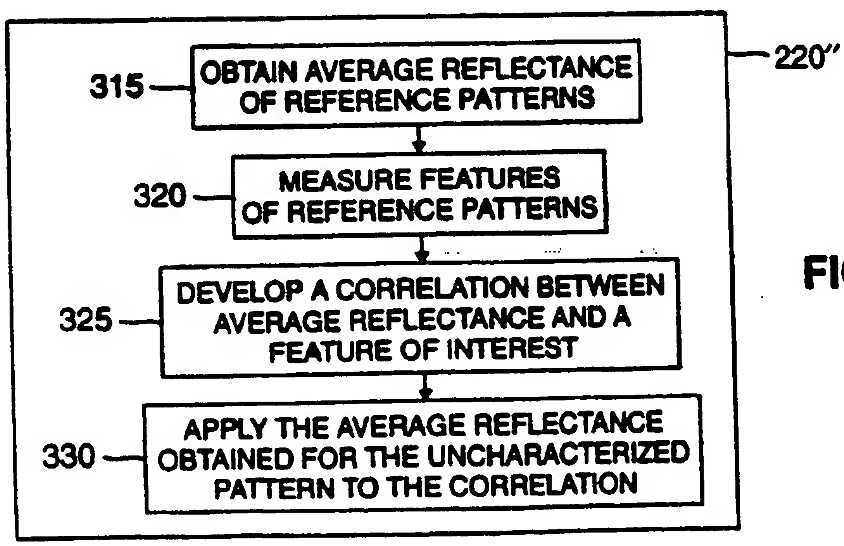

FIG. 5C

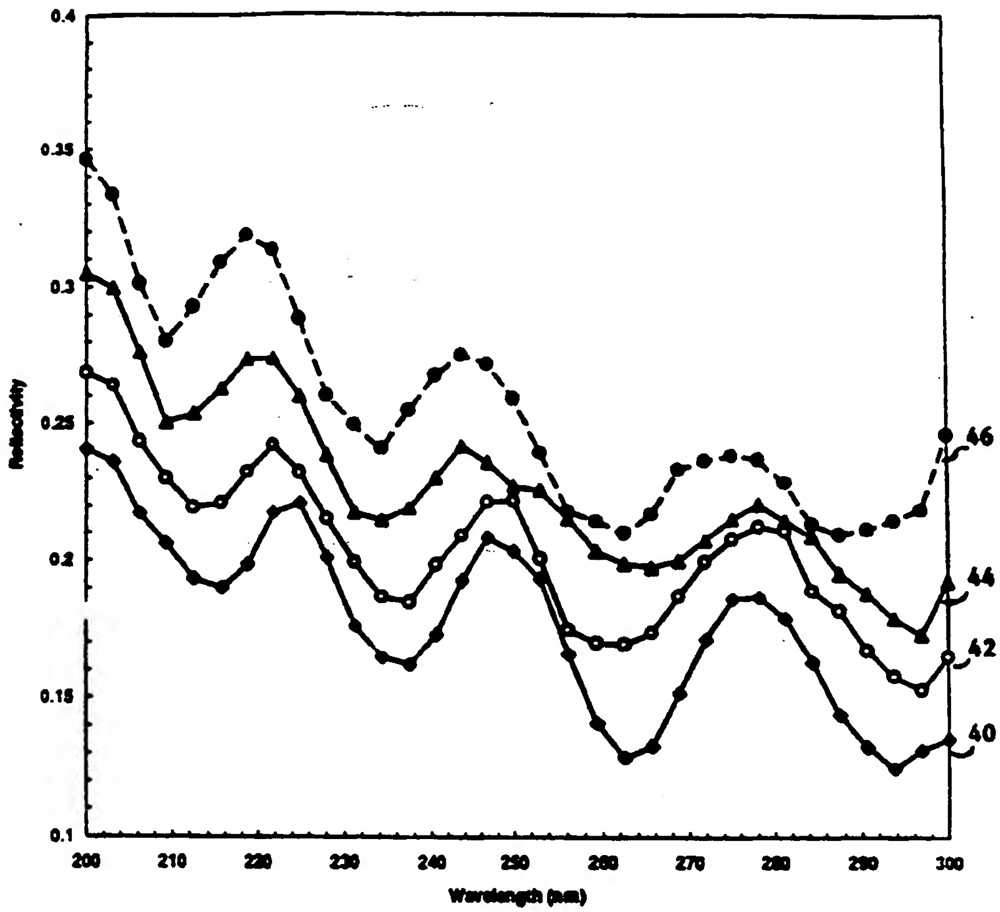
0.4
0.35
0.3
0.25
0.2
0.15
0.1
Reflectivity
200
210
220
230
240
250
260
270
280
290
300
Wavelength (nm)
46
44
42
40

FIG. 6

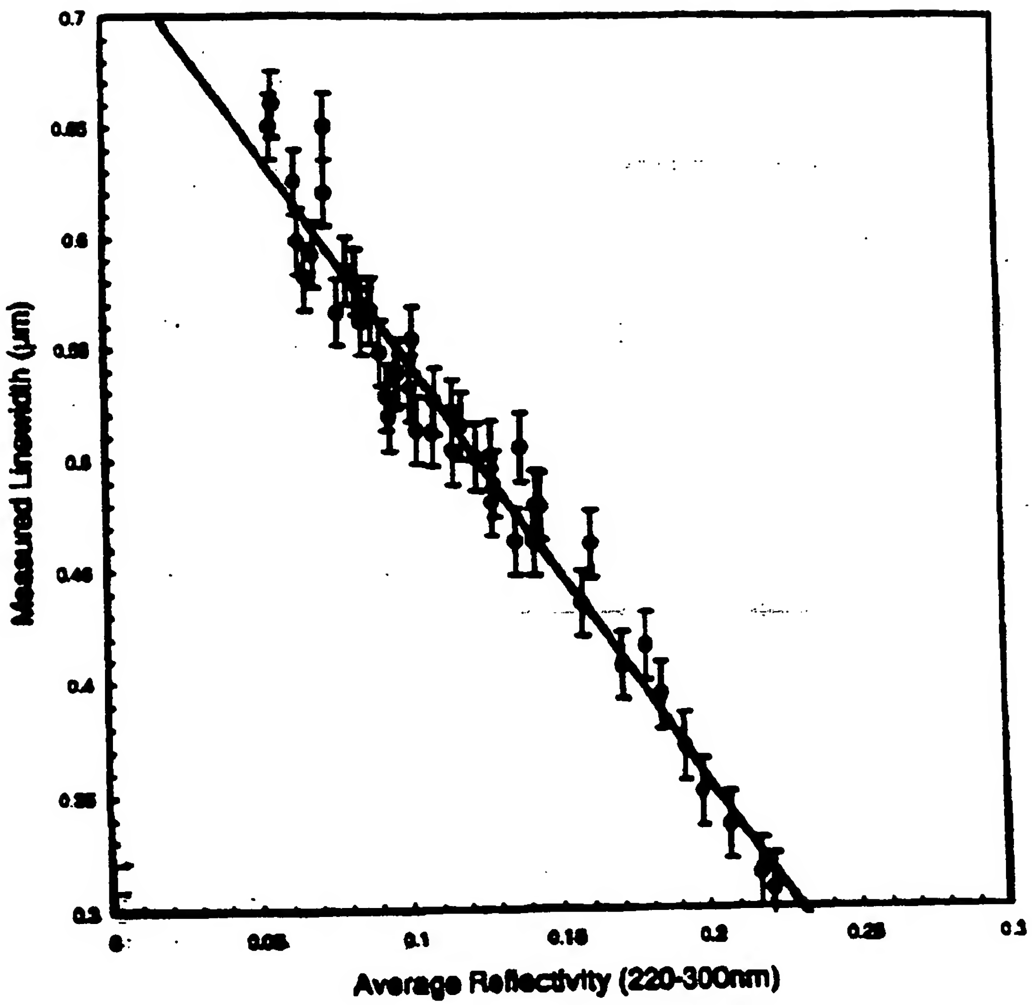
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
Measured Linewidth (µm)
0
0.05
0.1
0.15
0.2
0.25
0.3
Average Reflectivity (220-300nm)

FIG. 7

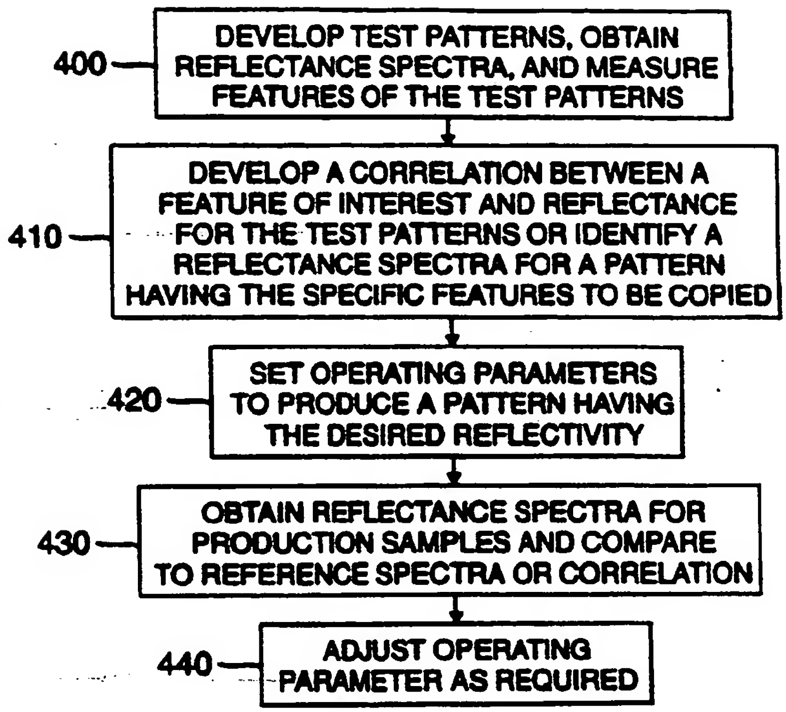
400
DEVELOP TEST PATTERNS, OBTAIN REFLECTANCE SPECTRA, AND MEASURE FEATURES OF THE TEST PATTERNS
410
DEVELOP A CORRELATION BETWEEN A FEATURE OF INTEREST AND REFLECTANCE FOR THE TEST PATTERNS OR IDENTIFY A REFLECTANCE SPECTRA FOR A PATTERN HAVING THE SPECIFIC FEATURES TO BE COPIED
420
SET OPERATING PARAMETERS TO PRODUCE A PATTERN HAVING THE DESIRED REFLECTIVITY
430
OBTAIN REFLECTANCE SPECTRA FOR PRODUCTION SAMPLES AND COMPARE TO REFERENCE SPECTRA OR CORRELATION
440
ADJUST OPERATING PARAMETER AS REQUIRED

FIG. 8A

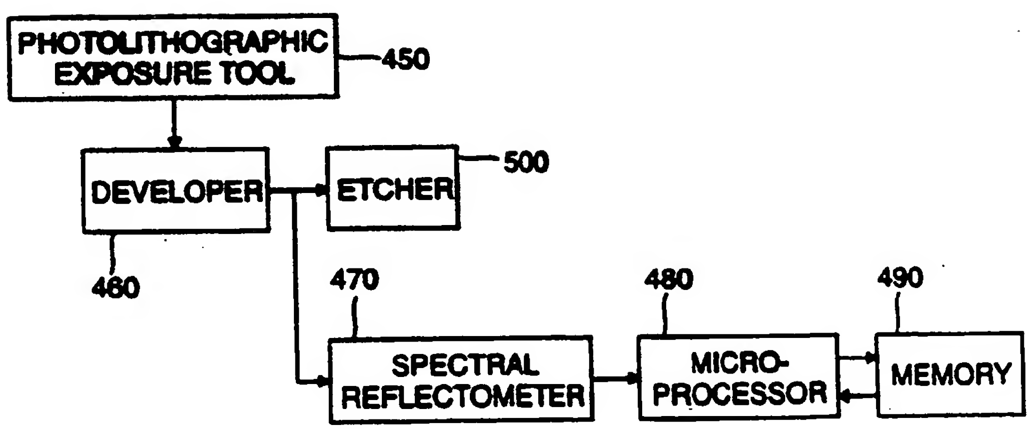
PHOTOLITHOGRAPHIC EXPOSURE TOOL
450
DEVELOPER
460
ETCHER
500
470
SPECTRAL REFLECTOMETER
480
MICRO-PROCESSOR
490
MEMORY

FIG. 8B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 0825

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	US-A-4 757 207 (CHAPPELOW RONALD E ET AL) 12 July 1988 * column 2, line 60 - column 4, line 58 * * figures 1-6 * ---	1,6,12, 17,19,20	G03F7/20
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 32, no. 4B, September 1989, NEW YORK, US, pages 391-392, XP002003937 ANONYMOUS: "Spectroscopic Pitch Measurement Technique" * the whole document * ---	1,6,12, 17,19,20	
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 32, no. 10A, March 1990, NEW YORK, US, pages 170-174, XP002003938 ANONYMOUS: "Phase-Sensitive Overlay Analysis Spectrometry." * the whole document * -----	1,6,12, 17,19,20	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G03F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 May 1996	Heryet, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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L : document cited for other reasons

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